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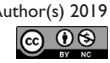

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Beholding the cosmos: Huygens' *Cosmotheoros* and the latter-day Copernicans

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Abstract

Christiaan Huygens, a founding father of modern physics and astronomy, speculated on extraterrestrial life toward the end of his life. Some of his speculations now seem quaint or naïve, but in other respects, Huygens was admirably enlightened. Huygens' thought was permeated by Copernicanism and the associated way of thinking that may be termed the principle of indifference. Modern descendants of this statistical mode of generating speculations has given rise to speculations that are, in their own way, as naïve and untenable as Huygens' argument for hemp on Jupiter.

Keywords

Christiaan Huygens, *Cosmotheoros*, extraterrestrial life, statistical fallacies, insufficient reason

Huygens' Planetarians

Who would have thought that there are sailing ships on Jupiter and Saturn? The Dutch scientist Christiaan Huygens (1629–1695), for one, believed so (Figure 1). Kepler had deemed these planets to be inhabited, since what purpose could else be served by moons that Earthmen cannot see with the naked eye?[1] Huygens took these ideas one step further, in his *Cosmotheoros*:

> If their Globe is divided like ours, between Sea and Land, as it's evident it is (else whence could all those Vapors in Jupiter proceed?) we have great reason to allow them the Art of Navigation, and not proudly ingross so great, so useful a thing to ourselves. Especially considering the great advantages *Jupiter* and *Saturn* have for sailing, in having so many Moons to direct their Course,

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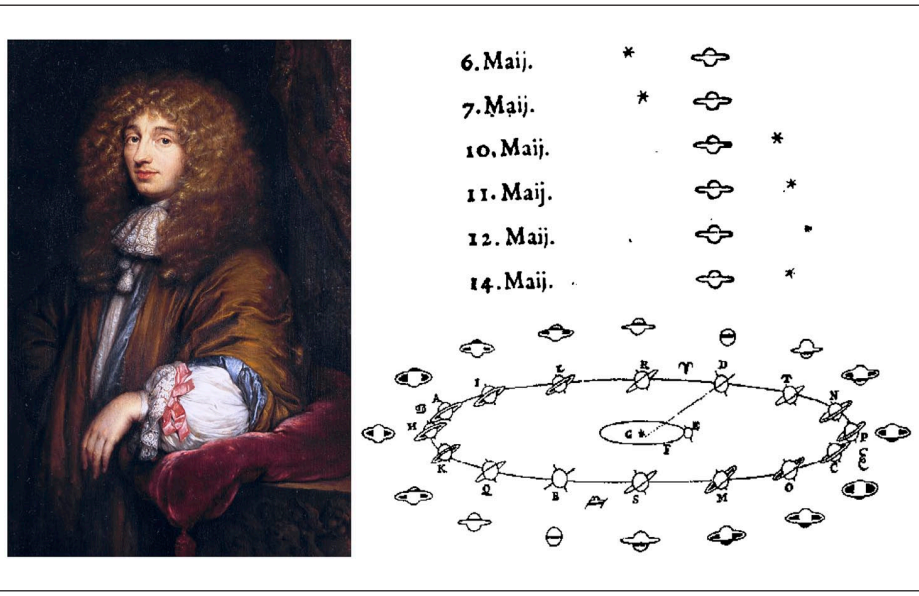

Figure 1. Christiaan Huygens ca. 1671 (left: portrait by Caspar Netscher, Haags Historisch Museum). Top right: Huygens' observations of Saturn's moon Titan on subsequent days during the month of May ("Maij"), Titan is indicated by an asterisk (*) as it orbits Saturn. Bottom right: diagram by Huygens explaining how the aspects of Saturn's rings change as seen from the Earth; both Earth and Saturn orbit the sun in the center (at G).

> by whose guidance they may attain easily to the Knowledge that we are not Masters of, of the Longitude of Places. And what a troop of other things follow from this allowance? If they have Ships, they must have Sails and Anchors, Ropes, Pullies, and Rudders, which are of particular use in directing a Ship's Course against the Wind, and in sailing different ways with the same Gale.[2]

Huygens saw an intellectual kinship between ourselves and the "Planetarians," which would manifest itself in a shared interest in the natural and mathematical sciences. As the above passage makes clear, he even allowed that they may be more advanced than us. He observes that moons are for navigation, which calls for sails and rope, and providence provides hemp for the purpose of making these, as he remarks elsewhere in the *Cosmotheoros*. Is it therefore reasonable to believe we will find hemp growing on gas giants? We may well laugh at Huygens, as we readily conceive of other means of ship propulsion, and we know that, even if there is solid ground deep inside a gas giant, it is mired in such extreme conditions that vegetation is out of the question. But surely in our own century, we are equally parochial in our own way. We invariably fail to imagine what we fail to imagine.

Cosmotheoros means something like beholder of the cosmos; κόσμος being the world or universe—in particular, when viewed as an ordered and harmonious system, while θεωρός means spectator, a word that has given us both *theory* and *theater*. Huygens the astronomer was not merely an armchair philosopher. He designed his own refracting

telescope, mapped out the Orion Nebula in great detail, and discovered Titan, the largest moon of Saturn. Furthermore, Huygens explained the mysterious sidereal shape-shifting of Saturn by proposing that the planet is surrounded by a ring.[3,4]

In contrast to Huygens' astronomical works, *Cosmotheoros* is almost entirely speculative.[3] The notion of our world as the center of the universe had been dealt a severe blow by Copernicus, who placed Earth in orbit around the sun, along with the other planets.[5] These were thereby put on an equal footing with our own home world, and had to be worlds in their own right. Huygens found it absurd to think that such vast heavenly bodies were put there by the creator merely for us to "peep at through a telescope."[2] In the following passage, he clearly sets out the idea that Earth is neither more nor less special than the other planets:

> Now should we allow the Planets nothing but vast Deserts, lifeless and inanimate Stocks and Stones, and deprive them of all those Creatures that more plainly speak their Divine Architect, we should sink them below the Earth in Beauty and Dignity; a thing that no Reason will permit.[2]

Our planet is just one of many, and not set apart by any special consideration other than the accidental fact that we happen to be its inhabitants. This principle can readily be generalized. Thus, our own sun is but one star among many others, and if our sun has a planetary system, the reasonable assumption is that this must be so because such systems are common, and therefore commonly found elsewhere as well:

> For then why may not every one of these Stars or Suns have as great a Retinue as our Sun, of Planets, with their Moons, to wait upon them? Nay there's a manifest reason why they should. For let us fancy our selves placed at an equal distance from the Sun and fix'd Stars; we should then perceive no difference between them.[2]

Huygens here clearly enunciates the *principle of indifference*. As with planets and stars ("suns"): we are but one of many, just another species endowed with a rational soul, and reason is elsewhere surely as it is with us:

> [The Planetarians'] Reason here must be exactly the same, and go the same way to work with ours, and that what's true in one part will hold true over the whole Universe; so that all the difference must lie in the degrees of Knowledge, which will be proportional to the Genius and Capacity of the Inhabitants.[2]

Vertiginous insignificance

In the old way of thinking, man was at the center of the world, which turned around him: Earth and all its denizens were there for man's dominion, and the rest of the universe revolved around Earth (Figure 2).[5] The Copernican revolution robbed Earth of what had hitherto been regarded as a unique, privileged position.[5] Perhaps even worse was that the new astronomy did not put anything else in that position. It was found that the sun is but one star of many in the Milky Way, all revolving around our galaxy's center (our sun, being 10 times heavier and twice as bright as the most-common-by-far M-type dwarf

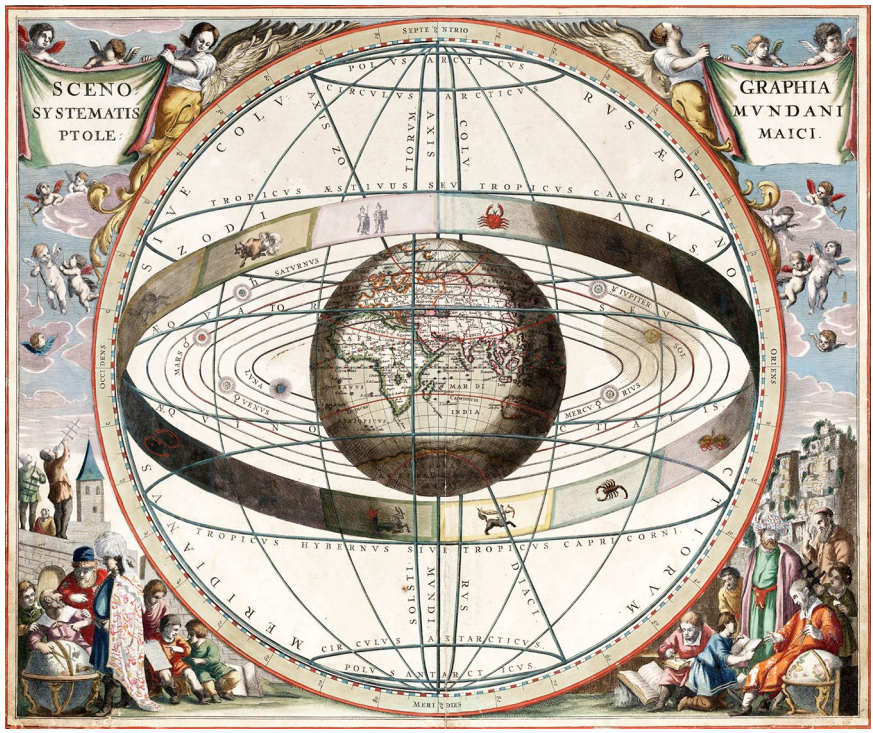

Figure 2. Geocentrism: *Scenographia systematis mundani ptolemaici* ("scenography of the Ptolemaic system of the world"). A 17th-century print by Johannes van Loon, showing the Earth at the center of the universe, with the planets in orbit around the earth and the fixed stars set in an outer sphere (the zone occupied by the constellations of the zodiac is emphasized as a belt bearing its signs).

star, is not quite as "run-of-the-mill" as modern-day Copernicans sometimes suggest).[6] In its turn, the Milky Way is but one galaxy among many in the Local Group, albeit one of the largest ones;[7] the Local Group is itself a small part of the Local Supercluster, centered on the Virgo Cluster, which happens to be a curiously galaxy-shaped grouping, but with *galaxies* in the place of stars,[8] all of which are flowing toward a location called the Great Attractor, along with the galaxies in many other superclusters, giving rise to an even larger supercluster called Laniakea, defined as the "gravitational basin of attraction" of the Great Attractor.[9]

But even the Great Attractor does not occupy a privileged position: although Laniakea's galaxies are currently converging on that point, they will not aggregate there for all eternity, and Laniakea will ultimately disperse.[10] In turn, Laniakea is only one lobe of the Pisces-Cetus Supercluster Complex,[11] itself but an ephemeral wisp in the Cosmic Web, which fills the Observable Universe and which occupies a million times more space.[12]

This relentlessly repeating litany ". . . itself but an outskirt of . . ." ad infinitum can be taken to support a nihilistic or areligious stance. Even if traditional (Abrahamic) religion naturally assumed anthropocentrism/geocentricism and was factually proven wrong on that score, the loss of privilege does not necessarily equate to the notion that ours is an insignificant corner of the universe, at least, if we measure insignificance by other places being more significant.

Are we a far-flung outskirt, far, far away from the "true" center of the universe? No: all places in the universe are equally insignificant, that is to say: equally privileged, each at the center of its own observable universe. More surprisingly, all locations witness essentially the same observable universe, even if each spot defines itself as the center of that universe by its local definition of "observable." The point is not that a privileged spot *elsewhere* just happens not to exist, it is that such a spot cannot exist in any physically meaningful sense.[13]

When we observe something that is a distance D away from us, and the signal by means of which we observe it (usually electromagnetic radiation) travels as fast as the laws of physics permit—which is c, the speed of light—we glean information about the state of the thing as it was, $T = D / c$ time units ago, as measured by our inertial frame of reference. Thus, we are always looking back in time. (Interstellar light signals do not always travel at c, as they may be scattered; but this is more akin to a relay race involving many photons, each of which does travel at c, with the relaying atoms introducing the added time loss. Neutrinos emanating from the same event, being of subliminal velocity but almost immune to scattering, may reach us ahead of the light of that event.)

For our sun, this time delay amounts to just over 8 min and, for the planets in our solar system, roughly between half and several hours.[14] The proper travel time between two locations tends to zero as the speed of travel tends to c (but then, in this limit, the separation in the direction of travel between any two locations likewise dwindles to zero).[15] One could somewhat fancifully interpret this as saying that it takes a photon *no time at all* to travel between any two points in the universe (but then, for a photon, the universe would be "squashed infinitely thin" in the direction of travel).

Stars and planets do not change much over the course of minutes or hours, so we seldom give much thought to these delays. It hardly matters if the sun we see is that of 8 min ago, by our proper clock. Incidentally, even the largest planet in our solar system is less than half a light second in diameter, a disparity in scale that gives us an inkling as to how *empty* space really is.[14]

In any case, the sun is hardly likely to have disappeared or, say, suddenly jumped to the side by a few hundred thousand kilometers. Similarly, we ignore, and for very good reason, the fact that D and T are readily interconvertible (via c) only in a flat Minkovsky frame anchored at our location; likewise, we usually gloss over the manner in which spacetime is distorted by the presence of matter and energy, both of which gravitate, as well as the expansion space undergoes as the photons are underway.[13] The meaning of an innocuous-looking phrase such as "somewhere else, *right now*" proves to be elusive.

As we look at ever more distant objects, these effects eventually become impossible to ignore. The farther we look, the further we are looking into the history of "our" observable universe. It becomes eerily irrelevant *where* we look. To observe comparatively nearby objects such as planets, stars, nebulae, or galaxies, we have to point

the instrument at where these bodies are located in the sky. That is to say, we have to "privilege" a direction in order to witness the desired phenomenon. But the further we look, the less direction seems to matter: point the instrument anywhere and you will see pretty much the same thing. The universe is almost perfectly *isotropic*, meaning that there is no privileged direction on the largest scales.[13]

Although Copernicus robbed us of the illusion of occupying center stage, the absence of any special direction is perhaps even more momentous. It severs the link between "observable universe" and "as seen from *here*"—since over *there*, as far away from us as possible, an observer perceives our location as being at the "edge" of the universe, and as ancient as we perceive theirs. The observable universe is, in any tangible sense, much the same for them as it is for us. When we talk about these distant observers in the present tense, we are thinking not so much of them sharing our own specious present, but rather of them and ourselves being kindred spirits; the Big Bang being roughly equally remote in our respective pasts.

In fact, our ability to share a well-defined reference to "cosmic time" with these distant beings relies on the combination of isotropy (no privileged direction) and homogeneity (no privileged place), which together constitute the *cosmological principle*—the principle of indifference writ large.[13] Believing that "above as below" is a leap of faith; we are sadly unable to visit the other side of the universe, to perform the experiments that would bolster our confidence that the laws of nature are the same everywhere and our universe is truly homogeneous. Nevertheless, the circumstantial evidence is compelling and rather direct when it comes to the isotropy of the universe.[13] We are not merely arguing from ignorance.

Insufficient reason

Mathematical statistics is the discipline *par excellence* to explicate the principle of indifference. We commonly throw dice willing to accept, at least as a working assumption, that the polka-dotted cubes are fair. In the absence of reasons to think otherwise, and considering its symmetries, we assign all outcomes an equal value. Even if we do suspect that the dice may be loaded, but we do not know how, it is still reasonable to assign all outcomes an equal value until evidence of any tinkering starts emerging.

In a probabilistic context, the principle of indifference is sometimes referred to as the *principle of insufficient reason*—insufficient reason, that is, to assume anything otherwise than equiprobability. Lest we fall into the fallacy of arguing from ignorance, we must ensure that the various outcomes or options do appear to be on an equal footing, for example, when we inspect a die or a coin for symmetry.

As a standard example of applying the principle of insufficient reason in a sound manner, consider what to expect when playing the lottery. Let us assume that we are discussing a regular kind of lottery where there are many more losers than winners, that is $N_{\text{lose}} >> N_{\text{win}}$. Let us also consider a typical participant who does not have insider knowledge or is in any other kind of privileged position. Then

$$\mathbb{P}\left[\text{participant wins}\right] \leq \frac{N_{\text{win}}}{N_{\text{win}} + N_{\text{lose}}}$$

with equality if none of the other participants disposes of privileged knowledge either. Since $N_{\text{lose}} >> N_{\text{win}}$, we deduce that $\mathbb{P}[\text{participant wins}] << 1$. The odds favor a loss.

To mitigate against these unfavorable odds, one can hedge one's bets by sharing a single ticket with other people. There are even lotteries that anticipate this stratagem and offer half a ticket, or a quarter of a ticket. The advantages are clear: one's chances of winning go up. Then again, winners have to share. The *reductio ad absurdum* of sharing lottery tickets is to team up with all other players, and collectively buy all the tickets. In this case, one can bypass the hassle altogether and simply hand over a little money to charity and a little more to the lottery organizer.

Another example: suppose you wake up one morning with total amnesia, so once more all you know is that you are a sentient being in a non-privileged position, should you then suppose that you find yourself in a populous country rather than a sparsely populated one? Well, if you were dropped on an empty bed chosen entirely at random, and all nations contain, at any given moment, a pro rata number of empty beds, then the answer is yes.

What the example of the lottery and the amnesiac waker have in common is that a background "experiment of chance" must be made explicit to render the problem well-defined in a probabilistic sense. Only when this is done can the principle of insufficient reason be meaningfully applied. In the absence of any such explication, the riddle is little more than a semantic or epistemic puzzle, akin to the hangman's paradox.

In the case of the lottery, these background premisses almost go without saying—the lottery is understood to work like any fair lottery—whereas in the case of the amnesiac waker, the required circumstances are absurd. Even if one were to wake up in these circumstances, one would not readily assume that the events of the past night included the choice of a country based on the global availability of empty beds. Indeed, should you wake up thinking like this, it is more likely that last night you were hit over the head.

The question of equal statistical weight may be difficult to settle when the random variable is continuous. Suppose that we have an observable X known to lie somewhere between X_1 and X_2. Careless application of the principle of insufficient reason assigns a probability density $(X_2 - X_1)^{-1}$ everywhere. Suppose now that another observable Y is related to X through some monotone function. The probability density of Y is given by $((dY/dX)(X_2 - X_1))^{-1}$. But all we know about Y is that it lies somewhere between two values, say Y_1 and Y_2; the principle of insufficient reason should thus give $(Y_2 - Y_1)^{-1}$, a constant probability density function. However, the derivative dY/dX is allowed to vary: a contradiction!

The resolution of the paradox is that X should be related to the density of some collection of underlying "outcomes" that *can* be assumed, with reason, to be equiponderous in probability. If each δX contains the same mass of outcomes, by weight of their amassed probability, its uniformity assumption is warranted, and if not, the required correction is easily derived from the density of states. The same can be done for Y, and we find that the formula $((dY/dX)(X_2 - X_1))^{-1}$ is now consistent.

Insufficient reason and the finiteness of the universe

The observable universe is finite. It might be bounded as well, in the way of a sphere centered on the observer. However, even the finite observable universe could be

unbounded, in which case, it would have to be multiply connected, like a torus. It is also possible that the observable universe is a negligible sliver of an infinite universe.

All you know for sure is that you are an intelligent observer. Now, a finite universe can only contain a finite number of such observers, whereas there are infinitely many intelligent observers in an infinite universe. You have no good reason to suppose yourself in a privileged position—you are surely not in any way special *sub specie æternitatis*—and there are many more intelligent beings in the infinite universe; unboundedly more, in fact, and thus the likelihood that your universe is finite must be infinitesimally small.

Is this a sound application of the principle of insufficient reason? As we saw above, what matters is the implied "experiment of chance" since the statistical argument by itself is as unassailable as it is simple. In terms of the lottery analogy, being a conscious mind is like buying a ticket and being in a finite universe is like winning. In terms of the amnesiac waking up, universes are like countries and minds like empty beds. In either case, the suggested "experiment of chance" is suspect.

Perhaps there is something oddly solipsistic about being asked to follow this argument, as an isolated conscious mind in this universe. You do know other people, most of whom either already take an interest in the question or can easily be persuaded to do so. Surely you are buying a ticket together with these people? In fact, are we not invested in this question *as a species*, by virtue of our shared humanity?

But even if entire planets buy a ticket at a time, there are still infinitely more tickets sold in an infinite universe, so this has not made a dent in the argument. Why stop at planetary parochialism, though? *We* ask the question collectively, as all intelligent beings in this, our universe. The relativistic failure of simultaneity precludes us from asking the question in a shared present tense. What we mean rather is a spiritual kinship to every civilization that becomes advanced enough to ask the question. So the collective intelligence of each universe then purchases a single ticket per universe. The underlying question is one of equiponderous "density of states": do we have billions of outcomes (intelligent minds) per planet, or just the one? Do we have billions per galaxy, or just the one? And so on . . . It does not even stop at the level of the universe, since there may well be a panoply of universes that continually spring into existence. We would do well to be suspicious of the idea that the question can be settled by arguing from insufficient reason.

Finding planetarians and counting their minds

For intelligent extraterrestrial life, we must look beyond our own solar system: our hopes are pinned on planets orbiting stars elsewhere. We saw that Huygens was an über-Copernican, imagining other planets very much like our own, complete with hemp and sailors. He was keen to stress the Planetarians' similarity to humans, endowing them with reason, mathematics, and natural science; to be social, to live in dwellings, and enjoy art; and exploit natural resources in a technological fashion. His view of their biology is predicated on the requisites these similar minds impose, chief among them the ability to *manipulate*:

> . . . we must necessarily give them hands, or some other Member, as convenient for all those uses, instead of [hands] [. . .] without their help and assistance men could never arrive to the improvement of their Minds in natural Knowledge.[2]

What "other Members" might there be that serve similar uses?

> Shall we give them an Elephant's Proboscis? 'Tis true, these Beasts [. . .] can perform such admirable feats with it, that it has not very improperly been call'd their Hand, tho indeed it is nothing but a Nose somewhat longer than ordinary. Nor do Birds show less Art and Design in the use of their Bills in the picking up their Meat, and the wonderful composure of their Nests.[2]

Nonetheless, perhaps for want of imagination, Huygens finds the human hand much more excellent. He seems overeager to endow his alien beings with human-like posture, on fairly unconvincing grounds:

> The Stature and Shape of Men [. . .] so fitly adapted to its design'd Uses, that it is not without [. . .] probability that the Planetarians have their Eyes and Countenance upright, like us, for the more convenient and easy Contemplation and Observations of the Stars.[2]

Huygens is quick to point out that it does not follow . . .

> . . . that they must be of the same shape with us. For there is such an infinite possible variety of Figures to be imagined, that [their anatomy and physiology] may be quite distinct and different from ours. How warmly and conveniently are some Creatures clothed with Wool, and how finely are others deck'd and adorn'd with Feathers?[2]

Huygens considers arthropods . . .

> . . . whose Flesh is on the inside of their Bones as 'twere. What if the Planetarians should be such? O no, somebody will say, it would be a hideous sight [. . .] I should not be at all moved with their ugly shape, if it were not, that hereby they would be deprived of that quick easy motion of their Hands and Fingers, which is so useful and necessary to them.[2]

It is the functionality and versatility of hands or similar manipulators that primarily concerns Huygens. Our subjective esthetic judgment should not enter into it:

> For 'tis a very ridiculous opinion, that the common people have got among them, that it is impossible a rational Soul should dwell in any other shape than ours [. . .] 'twould be a very pretty sight, pretty beyond all imagination, to see the odd ways, and the unusual manner of their setting about any thing, and their strange methods of living.[2]

Huygens rejects the then-popular notion that sentient aliens must look exactly like us because God would have made them too in his image, as he made us in his image, implying that all God's children must look alike—or, as modern TV sci-fi shows suggest, no more different than can be achieved by a resourceful make-up artist. Apparently, Huygens was of the view that the "image" in which humans are God-like should be taken not in the literal sense of outward appearance, but in that of disposing of divine appurtenances such as reason, morality, and a sense of justice.

Allowing that other planets might be inhabited was itself a daring proposition from a religious perspective, for either the Planetarians were eternally doomed, absent a

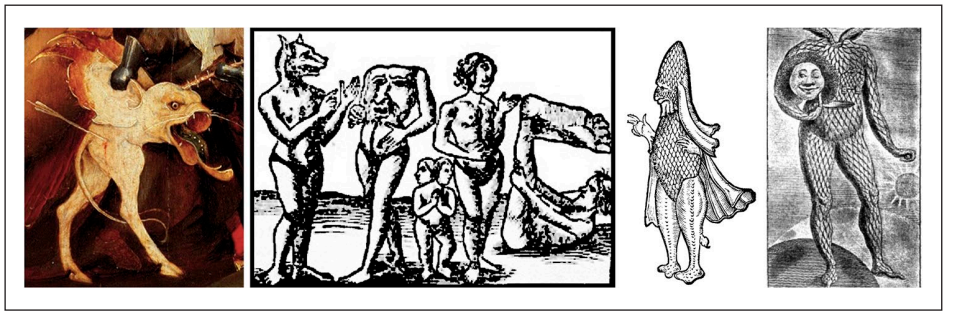

Figure 3. Depictions through the ages of freakish creatures from the unknown. Far left: *Triptych of the Temptation of St. Anthony* (detail) by Hieronymus Bosch (1501, Museu Nacional de Arte Antiga, Lisbon), a monster spawned by hell. Middle left: humanoid savages that inhabit faraway countries, featuring animal heads, faces on chests (and no head), double heads, or a single eye or foot (ca. 1517, Openbare bibliotheek Brugge). Middle right: sea-bishop, also known as bishop-fish (1575), a sea creature that was generally regarded as extant during Huygens' lifetime. Far right: denizen of the moon, with detachable head, by George Cruikshank (1877).

covenant with God mediated by Christ, unless the sacrifice on our planet extends to all intelligent life in the universe. Alternatively, alien worlds would each have received their own incarnation of Christ. To us, this is perhaps not a terribly grotesque idea, although admittedly yet another diminution of the cosmic import of events on planet Earth. However, in the 16th century, there could only have been one Christ (*Unus est Filius Dei* . . .).[16] Despite his forward-thinking attitude, Huygens admits he . . .

> . . . cannot without horror and impatience suffer any other figure for the habitation of a reasonable Soul. For when I do but represent to my Imagination or Eyes a Creature like a Man in every thing else, but that has a Neck four times as long, and great round saucer Eyes five or six times as big, and farther distant, I cannot look upon't without the utmost aversion, altho at the same time I can give no account of my Dislike.[2]

Reared as we are on science-fiction imagery, we may be disinclined to share this aversion—or perhaps Huygens simply imagined more keenly, and more sincerely, the horror that actually meeting such aliens "in the flesh" would entail. In late-medieval times, fantastical imagery was evoked in the portrayal of the denizens of hell, and almost-human creatures disfigured by grotesque features, of the sort imagined here by Huygens, were a staple of tales of faraway countries or the high seas; this imagery has remained remarkably similar, as it shifted gradually from denizens hell or *Terrae incognitae* to extraterrestrials (Figure 3).

Just like the amnesiac waking up adopts the assumption that he has awoken to a populous nation, so should we perhaps assume that we have become conscious on a particularly densely populated world. Since species with large population sizes tend to have smaller individuals, we should perhaps assume that we are small fry as intelligent denizens of the cosmos go, and that the average intelligent alien is perhaps a few hundred pounds heavier than we are.[17]

If this argument is to be assessed on the basis of the underlying "experiment of chance," it must be a *pre-existence doctrine* that asserts souls already exist, in advance the bodies they will inhabit. This is an idea found in many of the world's religions. In addition, a probabilistic element is needed: these souls are to be "dropped" at random and thus appear pro rata. It is in this sense that you are statistically independent of your fellow Earthlings, since you might have found yourself on any intelligently inhabited planet, on a strictly pro rata basis.

There is, once more, something oddly parochial and solipsistic about applying the "empty beds" argument to the "empty crania" of the yet-to-be-born. For one thing, the argument presupposes that conscious minds are cut of a similar cloth everywhere in the universe. As humans, we do usually experience our consciousness as unitary—despite the fact that cognitive processes are in fact a plurality. There can be little doubt that this apparent unitariness of mind is a consequence of the unitariness of our bodies. By contrast, a modular organism may well exhibit a certain fragmentariness of mind. Counting minds (instances of consciousness) could be meaningless to such organisms. There is no reason why there might not exist conscious beings elsewhere for whom individuality has such fluidity.

Conversely, humanity is grappling with the notion that some urgent problems will only be addressed if we learn, as a global population, to decide and act with unity of purpose on a planetary level. The ultimate result could be a consciousness on a planetary level. As far as the counting argument goes, it might seem obvious that such a planetary mind would count itself as "one." Or would it? In his novel *Solaris*, Stanislav Lem imagined a sentient, motile being that covers the entire surface of a planet.[18] Lem masterfully evokes the fundamentally impenetrable nature of Solaris' planetary mind. The Solaris creature appears to be akin to colony-forming organisms on Earth, as in the course of the novel, several quasi-independent humanoid Solarians bud off and appear to the astronauts, who are left to wonder whether these offshoots have a mind of their own.

In sum, we must conclude that it is foolhardy indeed to believe that the average size of alien intelligences can be inferred from threadbare statistical reasoning.

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References

1. Rosen E. *Kepler's conversation with Galileo's sidereal messenger. First complete translation, with an introduction and notes*. New York: Johnson Reprint Corporation, 1965.

2. Huygens C. *Cosmotheoros: celestial worlds discover'd: or, conjectures concerning the inhabitants, plants and productions of the worlds in the planets*. London: Timothy Childe, 1697.
3. Radelet-de-Grave P. L'Univers selon Huygens, le connu et l'imaginé. *Rev His Sci* 2003; 56: 79–112.
4. Chareix F. Experientia ac ratio. L'œuvre de Christiaan Huygens. *Rev His Sci* 2003; 56: 5–13.
5. Stoffel J-F. La révolution copernicienne et la place de l'homme dans l'Univers. Étude programmatique. *Rev Philos Louvain* 1998; 96: 7–50.
6. Beech M. Since when was the sun a typical star? *J Roy Astron Soc Can* 2011; 105: 232–237.
7. Van den Bergh S. *The galaxies of the local group* (Cambridge Astrophysics Series S35). Cambridge: Cambridge University Press, 2000.
8. De Vaucouleurs G. The local super-cluster of galaxies. *Nature* 1958; 182: 1478–1480.
9. Tully RB, Courtois H, Hoffman Y, et al. The Laniakea supercluster of galaxies. *Nature* 2014; 513(7516): 71–73.
10. Chon G, Böhringer H and Zaroubi S. On the definition of superclusters. *Astron Astrophys* 2015; 575: L14.
11. Tully RB. More about clustering on a scale of 0.1 C. *Astrophys J* 1987; 323: 1–18.
12. Courtois HM, Pomarède D, Tully RB, et al. Cosmography of the local universe. *Astron J* 2013; 146: 1–14.
13. Dray T. *Differential forms and the geometry of general relativity*. New York: CRC Press, 2015.
14. Spohn T, Breuer D and Johnson TV. *The encyclopedia of the solar system*. Amsterdam: Elsevier, 2014.
15. d'Inverno R. *Introducing Einstein's relativity*. Oxford: Oxford University Press, 1991.
16. Lewis JR (ed.) *The gods have landed: new religions from other worlds*. Albany, NY: SUNY Press, 1995.
17. Griffiths S. Aliens may be the size of polar bears: formula calculates extraterrestrials have a mass of 650 lbs (if they exist, of course). *Daily Mail*, 6 April 2015, https://www.dailymail.co.uk/sciencetech/article-3027534/Forget-little-green-men-aliens-size-POLAR-BEARS-Formula-calculates-mass-extraterrestrials-650lbs-exist-course.html
18. Lem S. *Solaris*. Warsaw: Wydawnictwo Ministerstwa Obrony Narodowej, 1961.

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Hugo van den Berg has written on several problems in theoretical biology, e.g. in organismal physiology, lifting the fitness concept to a variational setting, allowing inference of essential dynamic properties whenever these are suitably delimited by physico-chemical constraints; in electrophysiology, mathematical foundations for a general methodology to accurately predict excitability properties at the cellular and organ levels on the basis of transcriptomics data; in immunology, he predicted a novel physiological phenomenon, viz. the T-cell receptor switching epitopes controlled by the co-receptor CD8, and pioneered a widely used TCR epitope prediction method.